Lecture 26

Particle detectors
Particle identification
Accelerators I
Silicon detectors, silicon strip detectors

Single sided w/capacitive readout

CDF Silicon VerteX

- Inaccessible for years! "Robust"
- Other detector concepts
  - Double sided or drift laterally
  - Pixels w/bump bonding to readout
- Radiation damage a major concern
- Replace silicon crystal with diamond
Scintillator basics

- Rutherford used scintillation
  - ZnS screen - flashes
  - Eyes were photo detectors
- Photo-multiplier tube (PMT)

Photocathode Q.E.
Scintillators

- **Inorganic (high output, slow)**
  - Crystals NaI, CsI, BaF₂
  - Glasses PbWO₄, Ba₄Ge₃O₁₂
  - Cryogenic liquids LAr (UV)
  - all are temperature dependent!

- **Organic (low output, fast fluorescence)**
  - monocrystals naphthalene, anthracene
  - solvents (mineral oil) + waveshifters
  - plastic + waveshifters + polymerization
  - fluorescence in UV, must be waveshifted
Calorimeters

- **Electro-magnetic shower (Lecture 12)**
  - Pair production / Bremsstrahlung
  - Energy deposited as ionization

- **Total absorption calorimeter**
  - Crystals for photons & electrons
  - Liquid Argon ionization & tracking for electromagnetic and hadronic

- **Sample fixed % of ionization**

- **EM sampling calorimeters (15%)**
  - Pb plates ($0.5X_0 = 3$ mm)
  - Scintillator/LAr filler (4-6mm)

- **Hadronic sampling calorimeters (5%)**
  - Fe plates (6-10 mm, length = 2m)
  - Scintillator/LAr filler (6mm)
Particle ID techniques

**Time of flight**

\[ \frac{\delta m}{m} = \gamma^2 \frac{\delta t}{t}; \]

**Fermilab's CDF parameters:**

\[ t_c = 5 \text{ ns}; \quad \delta t = 0.1 \text{ ns}; \quad \frac{\delta t}{t} \sim 0.05 \]

\[ \gamma = \frac{E}{m} \sim 3; \quad \frac{\delta m}{m} = 9 \left(0.05\right) = 45\% \]

\[ E_\pi \leq 0.5 \text{ GeV}; \quad E_K \leq 1.5 \text{ GeV}; \quad E_p \leq 3 \text{ GeV} \]

separate: \( e/\pi/\overline{K}/p \) \( e\pi/\overline{K}/p \) \( e\pi K/p \)

**Ionization sampling**

**Cerenkov radiation**

\[ \beta \geq \beta_{thr} = \frac{1}{n} \]

\[ n : \text{refractive index} \]

\[ l_{\text{light}} = (c/n)\Delta t \]

\[ l_{\text{part}} = \beta c \Delta t \]

\[ \cos \theta_C = \frac{1}{n\beta} \]

with \( n = n(\lambda) \geq 1 \)
Accelerators - particle sources

- Ion sources
  - Positive ions (e.g., H\(^+\), Au\(^{79}\))
  - Negative ions (H\(^-\)) for injection into positive beams

- DC e-guns: 50-500 kV acceleration
  - thermionic emission (grid pulsed)
  - laser pulse on photocathode

- RF e-guns
  - cathode one wall of an RF cavity
  - >10 MeV, low “emittance” beams

- Positron sources
  - photon conversions (\(\gamma \rightarrow e^+e^-\))
  - 20 GeV to >100 GeV electrons

- Antiproton sources
  - 120 GeV proton collisions, Li lens.
**Accelerators - Linear accelerator (Linac)**

- **Drift tube (Alvarez) linac**
  - Fermilab’s
  - 201 MHz
  - 116 MeV Linac

- **RF cavity linac**
  - Fermilab’s
  - 805 MHz
  - 400 MeV Linac
Cyclotrons

• Continuous beam cyclotron
  
  Constant frequency
  
  \[ p = mv = 0.3qBR \]
  
  \[ \omega = \frac{v}{R} = \frac{0.3qB}{m} \quad (m \text{ in GeV/c}^2) \]

• Relativistic cyclotron
  
  \[ \omega \text{ depends on } v \text{ and } R \]
  
  \[ \rightarrow \text{ pulse or } B(r) \]

  \[ p = \gamma mv = 0.3qBR \]
  
  \[ \omega = \frac{v}{R} = \frac{0.3qB}{\gamma m} \quad (m \text{ in GeV/c}^2) \]

\[ q = 1, \quad p = 2 \text{ GeV/c}, \quad R = 1m \]

\[ B = \frac{p}{0.3R} = \frac{2}{0.3(1)} = 6.7 \text{ T} = 67 \text{ kgauss} \]

Needs superconducting magnet!
Quadrupoles

For positive particles moving into the page, Quadrupole magnet below will focus in the vertical plane and defocus in the horizontal plane.

Quadrupole doublets, second rotated $90^\circ$ wrt the first

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

is positive for a large range of focal lengths and $d \Rightarrow \text{net focusing both radially and vertically}$

**V-Focus**

**H-Defocus**

**horizontal**

**vertical**